Weight-length relationships for 11 chondrichthyan species in the eastern Adriatic Sea

by

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RÉSUMÉ. - Relations taille-poids pour 11 espèces de chondrichtyens de l'Adriatique orientale.

Les relations taille-poids (WLR) sont données pour 11 espèces de chondrichtyens. Elles ont été établies à partir d'échantillons pêchés au chalut et au trémail, en mer Adriatique orientale, entre 1997 et 2001. Ces espèces constituent, en nombre et en poids, plus de 90% de la capture totale des chondrichtyens dans la zone étudiée. Le coefficient *b* dans la relation $W = aL^b$, varie entre 2,851 et 3,397. La comparaison de nos valeurs avec les données disponibles pour l'Adriatique et la Méditerranée, montre qu'il existe des variations notables dans les valeurs du coefficient *b*.

Key words. - Chondrichthyes - MED - Adriatic Sea - Weight-length relationships.

The weight-length relationship (WLR) for fishes from the Adriatic Sea and the Mediterranean refers mainly to Osteichthyes, especially for those of commercial importance (Petrakis and Stergiou, 1995; Dulčić and Kraljević, 1996; Merella *et al*., 1997; Stergiou and Moutopolous, 2001; Morey *et al*., 2003). Concerning cartilaginous fish in the eastern Adriatic, WLRs are only available for *Scyliorhinus stellaris* (Županović, 1961), *S. canicula* (Jardas, 1979) and *Mustelus mustelus* (Dulčić and Kraljević, 1996).

The WLRs have several applications, namely on fish biology, physiology, ecology and fisheries assessment. In a given geographic region, the WLRs are useful for the estimation of weight-at-age from total reported catch weight and length-frequency distributions (Petrakis and Stergiou, 1995). Furthermore, the WLR is useful for estimating condition (Safran, 1992), production and biomass of a population (Anderson and Gutreuter, 1983) or comparisons of populations from different regions (Goncalves *et al*., 1997).

In the present study, the parameters of WLRs are reported for 11 chondrichthyes species caught in Croatian waters (Eastern Adriatic Sea) using bottom-trawl and trammel net of various mesh sizes. These species made up more than 90% by both number and weight of the total Chondrichthyes caught in this area (Jardas, 1996).

MATERIAL AND METHODS

Samplings took place in the Eastern Adriatic Sea during 1997-2001 (Fig. 1). The chondrichthyans were collected with bottom trawl (stretched cod-end mesh size of 22-24 mm) and bottom trammel nets. The mesh sizes (bar length) of the trammel nets were 28, 30, 32, 35 and 40 mm.

All specimens were measured (total length - TL and pelvic length - PL for Batoidea) to the nearest 0.1 cm, and weighed to the nearest 1 g. Sex was assigned macroscopically. The relationship between weight and total length, $W = aL^b$, was converted into its logarithmic expression: $\ln W = \ln a + b \ln L$. The parameters *a* and *b* were calculated by last-squares regression, as was the coefficient of correlation (R^2).

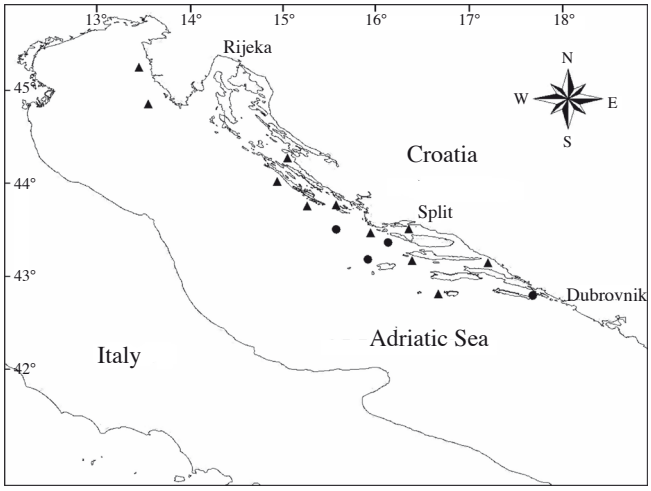

Figure 1. - Locations of bottom trawl (●) and bottom trammel net (▲) sampling stations in the Eastern Adriatic Sea for the 11 chondrichthyes species. *[Localisation des stations d'échantillonnage au chalut (●) et au trémail (▲) en mer Adriatique orientale pour les 11 espèces de chondrichtyens.]*

Statistical methods used for data include the usual calculations of means and standard deviations. Significance of constant *b* differences in relation to the hypothesis of isometric growth ($b = 3$) was tested with the $\hat{t}$-test (Pauly, 1983). To test for possible significant differences between sexes we used analysis of covariance (ANCOVA). *T*-test was used to compare the *b* values between this study and some of previously reported in the Adriatic Sea and Mediterranean.

RESULTS AND DISCUSSION

The sample size, length range, mean length (± SD), weight range and mean weight (± SD) of males, females and sexes combined for each species are presented in table I. Parameters *a* and *b* of the WLRs, standard error of *b*, coefficient of correlation R^2 and $\hat{t}$-values are presented in table II. In the latter, the results for sex combined are presented for species in which there are not signifi-

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Table I. - Number (N), length range (TL: total length, PL: pelvic length), mean length (± SD), weight range and mean weight (± SD) of males (M), females (F) and sexes combined for 11 chondrichthyes species caught in the Adriatic Sea during the 1997-2001 period. Species are listed in alphabetical order. *[Nombre (N), gamme de taille (TL : longueur totale, PL : longueur pelvienne), longueur moyenne (± SD), gamme de poids et poids moyen (± SD) des mâles (M) et femelles (F) et sexes confondus pour 11 espèces de chondrichtyens capturées en mer Adriatique pendant la période 1997-2001. Les espèces sont listées par ordre alphabétique.]*

Species	Sex	N	Length range (cm)	Mean length ± SD	Weight range (g)	Mean weight ± SD
Dasyatis pastinaca (L, 1758)	M	49	31.0-71.4	48.0 ± 11.8	145.2-3850	1000.9 ± 921.3
	F	43	17.9-95.2	46.3 ± 15.0	82.0-7500	989.0 ± 1335.9
	Total	92	PL 17.9-95.2	46.9 ± 14.2	82.0-7500	993.1 ± 1276.1
Mustelus asterias (Cloquet, 1821)	M	34	21.5-84.0	66.4 ± 22.3	120.4-6750	1252.7 ± 1579.4
	F	33	19.1-117.3	75.5 ± 27.2	150.3-8750	1752.8 ± 2243.5
	Total	67	TL 19.1-117.3	72.8 ± 26.0	120.4-8750	1521.2 ± 2002.1
Mustelus mustelus (L, 1758)	M	56	25.7-141.4	55.7 ± 25.1	65.2-9503	858.9 ± 1444.2
	F	59	31.6-148.3	59.3 ± 24.2	85.2-9560	944.0 ± 1532.2
	Total	115	TL 25.7-148.3	58.6 ± 24.8	65.2-9560	926.1 ± 1511.1
Myliobatis aquila (L, 1758)	M	78	44.6-90.8	64.7 ± 12.9	200.0-2100	837.6 ± 530.9
	F	53	12.9-129.0	68.6 ± 23.1	10.1-7800	1357.1 ± 1511.4
	Total	131	PL 12.9-129.0	66.1 ± 15.6	10.1-7800	1049.9 ± 1146.3
Raja clavata (L, 1758)	M	256	11.0-85.1	42.1 ± 18.6	10.3-5500	784.2 ± 1008.8
	F	278	11.4-105.0	45.7 ± 22.7	10.9-7000	1145.3 ± 1588.0
	Total	534	PL 11.0-105.0	44.5 ± 21.2	10.3-7000	941.1 ± 1399.6
Raja miraletus (L, 1758)	M	144	13.4-48.7	32.3 ± 8.6	10.4-528.6	183.8 ±131.0
	F	195	13.6-50.0	32.8 ± 8.4	11.0-632.5	201.9 ± 141.7
	Total	339	PL 13.4-50.0	32.6 ± 8.4	10.4-632.5	189.9 ± 136.2
Scyliorhinus canicula (L, 1758)	M	443	15.1-50.8	36.5 ± 6.3	10.2-501.0	151.7 ± 83.1
	F	326	19.0-52.2	35.5 ± 6.8	20.4-520.4	152.8 ± 94.7
	Total	769	TL 15.1-52.2	36.2 ± 6.4	10.2-520.4	152.6 ± 90.1
Scyliorhinus stellaris (L, 1758)	M	45	21.4-93.2	49.5 ± 20.4	70.6-2901	743.5 ± 894.8
	F	62	16.1-90.2	49.6 ± 19.7	10.5-3499	805.2 ± 947.4
	Total	107	TL 16.1-93.2	49.6 ± 19.9	10.5-3499	769.8 ± 910.6
Squalus acanthias (L, 1758)	M	147	21.5-84.0	47.6 ± 16.4	30.5-2135	539.2 ± 495.6
	F	274	19.1-117.3	50.0 ± 24.4	20.6-6825	1252 ± 1403.7
	Total	421	TL 19.1-117.3	49.2 ± 22.1	20.6-6825	946.8 ± 1266.8
Squalus blainvillei (Risso, 1826)	M	40	23.6-79.4	49.2 ± 10.3	50.5-800.8	523.6 ± 185.3
	F	48	23.0-74.5	51.6 ± 11.5	40.2-1981	729.4 ± 442.1
	Total	88	TL 23.0-79.4	50.8 ± 10.9	40.2-1981	644.1 ± 292.6
Torpedo marmorata (Risso, 1810)	M	179	7.2-33.0	21.5 ± 5.0	6.1-564.2	221.0 ±126.6
	F	208	10.2-50.5	25.5 ± 8.9	24.8-2560	445.3 ± 397.7
	Total	387	PL 7.2-50.5	24.6 ± 7.9	6.1-2560	362.7 ± 301.4

cant differences between sexes. The application of all length-weight relationships should be limited to the observed length ranges.

The sample size ranged from 67 individuals, for *Mustelus asterias*, to 769, for *Scyliorhinus canicula*. The R^2 values ranged from 0.909, for *Myliobatis aquila* to 0.987 for *Squalus acanthias,* and all regressions were highly significant ($p < 0.001$). The *b* values ranged from 2.851 (S.E. = 0.023), for *Torpedo marmorata* to 3.397 (S.E. = 0.065), for *Dasyatis pastinaca*.

Significant differences of *b* values between sexes were observed for *Mylobatis aquila* (ANCOVA: F = .05, 1, 384 = 4.18; Fcrit. = 3.84), *Raja clavata* (ANCOVA: F = .05, 1, 531 = 4.04; Fcrit. = 3.84) and *Scyliorhinus canicula* (ANCOVA: F = .05, 1, 766 = 42.77; Fcrit. = 3.84) (Tab. II). Isometric growth was established for *Scyliorhinus stellaris, Mustelus mustelus, M. asterias, Raja miraletus, Mylobatis aquila* and *Squalus blainvillei*. *Scyliorhinus canicula, Dasyatis pastinaca, Squalus acanthias, Raja clavata* and separate males of *Myliobatis aquila* showed positive allometric growth, while *Torpedo marmorata* showed negative allometric growth (Tab. II).

Weight-length relationships have been published for eight chondrichthyan species in the Adriatic Sea and the Mediterranean (Tab. III). To the best of our knowledge, no information was available for *Mustelus asterias, Squalus acanthias* and *Myliobatis aquila* in the Mediterranean. The comparison of the *b* values obtained in our study and some of previously reported results in the Adriatic Sea and Mediterranean, indicates variation in the *b* values. However, WLRs for *Mustelus mustelus, Raja miraletus* (Southern Adriatic), *Scyliorhinus canicula* (Balearic Islands and Iberian coast), *Scyliorhinus stellaris* (Adriatic Sea), *Dasyatis pastinaca* and *Squalus blainvillei* (Balearic Islands), differed significantly from our results (Tab. III). The variation in the *b* exponents for a same species could be attributed to differences in sampling, sample size or length ranges. In addition, growth increment, food, environmental conditions, such as temperature, salinity, seasonality, as well as differences in age and stage of maturity can also affect the value of *b* (Shepherd

Species	Sex	*a*	*b*		S.E. (*b*)	R^2	$\hat{t}$
Dasyatis pastinaca	Total	0.0021	3.397	P	0.065	0.956	4.066
Mustelus asterias	Total	0.0020	3.079	I	0.055	0.979	1.436
Mustelus mustelus	Total	0.0021	3.069	I	0.053	0.963	1.288
*Myliobatis aquila**	M	0.0008	3.299	P	0.104	0.929	2.868
	F	0.0023	3.057	I	0.139	0.904	0.410
	Total	0.0016	3.134	I	0.087	0.909	1.544
*Raja clavata**	M	0.0019	3.282	P	0.033	0.981	9.952
	F	0.0012	3.390	P	0.030	0.978	12.930
	Total	0.0015	3.344	P	0.021	0.978	16.000
Raja miraletus	Total	0.0048	2.986	I	0.034	0.956	0.384
*Scyliorhinus canicula**	M	0.0015	3.166	P	0.033	0.953	5.009
	F	0.0007	3.380	P	0.048	0.938	7.807
	Total	0.0012	3.250	P	0.030	0.936	8.159
Scyliorhinus stellaris	Total	0.0041	3.000	I	0.048	0.973	0.018
Squalus acanthias	Total	0.0020	3.150	P	0.017	0.987	8.614
Squalus blainvillei	Total	0.0035	3.062	I	0.069	0.964	0.898
Torpedo marmorata	Total	0.0297	2.851	N	0.023	0.946	4.898

Table II. - Parameters *a* and *b* of the relationships ($W = aL^b$), standard error of *b* (S.E.), coefficient of correlation R^2, and $\hat{t}$ -values for 11 chondrichthyes species caught in the Adriatic Sea (I: isometry; P: positive allometry; N: negative allometry). *Significant differences (ANCOVA) of *b* values between males (M) and females (F). *[Paramètre* a *et* b *de la relation ($W = aL^b$), erreur standard pour* b *(S.E.), coefficient de corrélation R^2, et valeurs de $\hat{t}$ pour 11 espèces de chondrichtyens capturées en mer Adriatique (I : isométrie ; P : allométrie positive ; N : allométrie négative). * Différences significatives (ANCOVA) des valeurs de* b *entre mâles (M) et femelles (F).]*

Table III. - Number of specimens (N), length ranges (TL or PL), *a* and *b* values for those species compared between this study and data of the Adriatic Sea and Mediterranean (Italian and Greek waters, Western Mediterranean). * *b* values significantly different from those in our study. *[Nombre de spécimens (N), gamme de taille (TL ou PL), valeurs* a *et* b *pour les espèces de cette étude comparées aux données de la mer Adriatique et de la Méditerranée (eaux italiennes et grecques, Méditerranée occidentale). * Valeurs de* b *significativement différentes de celles de notre étude.]*

Species	Authors	Areas	N	Range (cm)		a	*b*
Dasyatis pastinaca	Morey *et al*. (2003)	Balearic Islands and Iberian coast	44	PL	15.1-53.9	0.0498	2.99*
Mustelus mustelus	Dulčić and Kraljević (1996)	Adriatic Sea	16	TL	38.0-75.0	0.0069	2.75*
Raja clavata	Merella *et al*. (1997)	Balearic Islands	18	PL	14.5-38.1	0.0024	3.20
Raja miraletus	Merella *et al*. (1997)	Balearic Islands	28	PL	16.6-41.0	0.0018	3.25
Raja miraletus	Stergiou and Moutopolous (2001)	Greek waters	16	PL	25.6-49.3	0.0025	3.29
Raja miraletus	Ungaro (2001)	Southern Adriatic	10	PL	15.0-51.0	0.0010	3.43*
Scyliorhinus canicula	Jardas (1979)	Adriatic Sea	671	TL	9.6-49.0	0.0090	3.30
Scyliorhinus canicula	Merella *et al*. (1997)	Balearic Islands	262	TL	7.5-42.1	0.0016	3.16
Scyliorhinus canicula	Morey *et al*. (2003)	Balearic Islands and Iberian coast	99	TL	40.9-53.4	0.0374	2.37*
Scyliorhinus stellaris	Županović (1961)	Adriatic Sea	20	TL	31.2-80.4	0.0035	4.02*
Squalus blainvillei	Cannizzaro *et al*. (1995)	Italian waters	1850	TL	15.0-90.0	0.0036	3.07
Squalus blainvillei	Merella *et al*. (1997)	Balearic Islands	27	TL	19.5-35.0	0.0012	3.37*
Torpedo marmorata	Morey *et al*. (2003)	Balearic Islands and Iberian coast	28	PL	17.2-45.4	0.0550	2.94

and Grimes, 1983; Weatherley and Gill, 1987, Dulčić and Kraljević, 1995).

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